



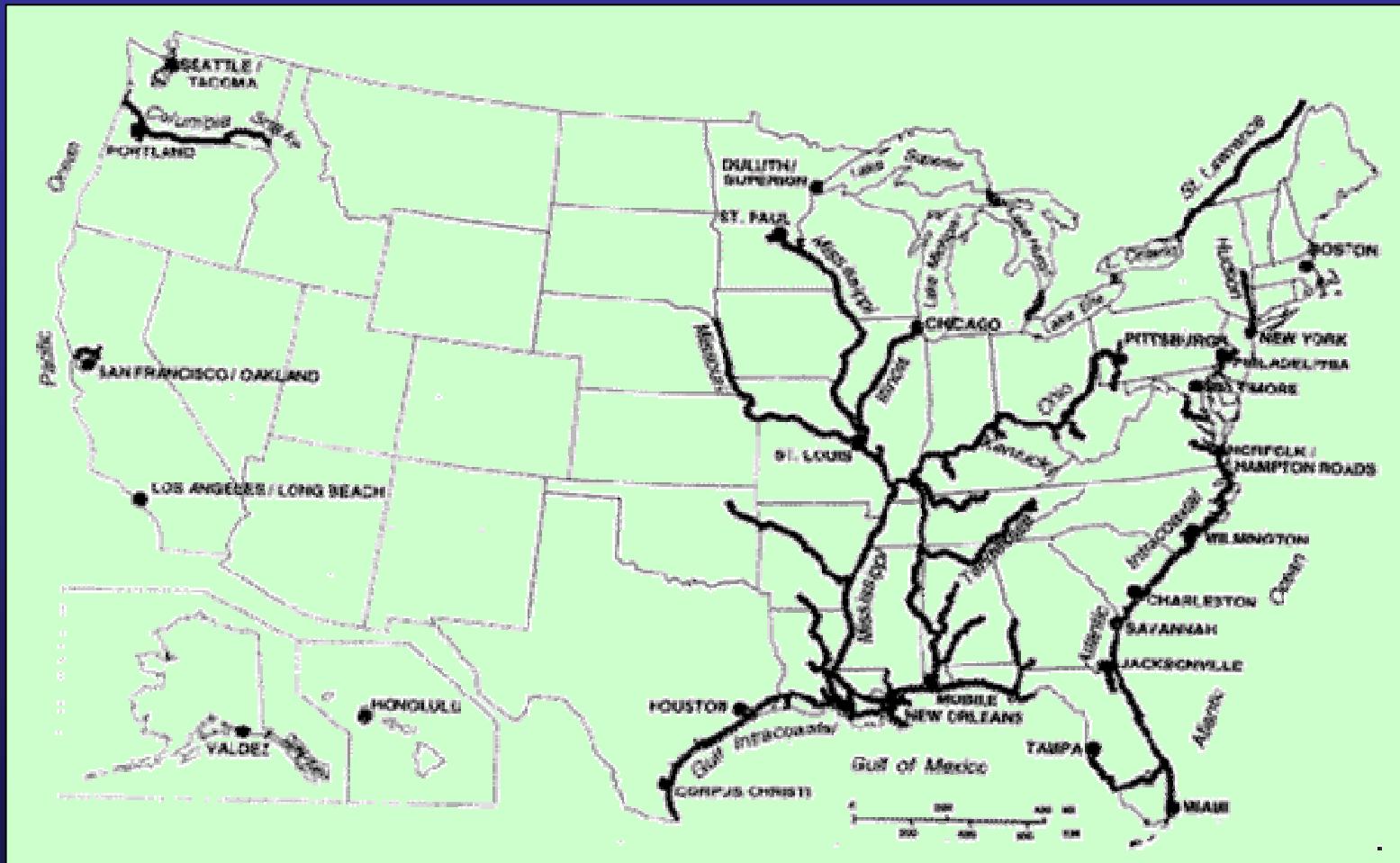
# Linking Biological Production with Hydrology and Hydraulics in Large Rivers

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U.S. Department of the Interior  
U.S. Geological Survey

*Mississippi River  
near Muscatine IA*

# Our large rivers have been modified for navigation, flood control and power generation



Courtesy U.S. Army Corps of Engineers



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# Business of the Mississippi River

*“Father of Waters”*

- **People:** 30 million residents
- **Commerce:** >120 million tons/yr shipping; 60% of corn and 45% of soybean exports
- **Tourism:** \$6.6 billion/yr from 12 million visitor-days; 143,000 recreation/tourism jobs
- **Ecological assets:** Flyway for 60% of North American bird species; 297,000 acres in National Refuge System; 240 species of fish

# Same river, different water-management strategies



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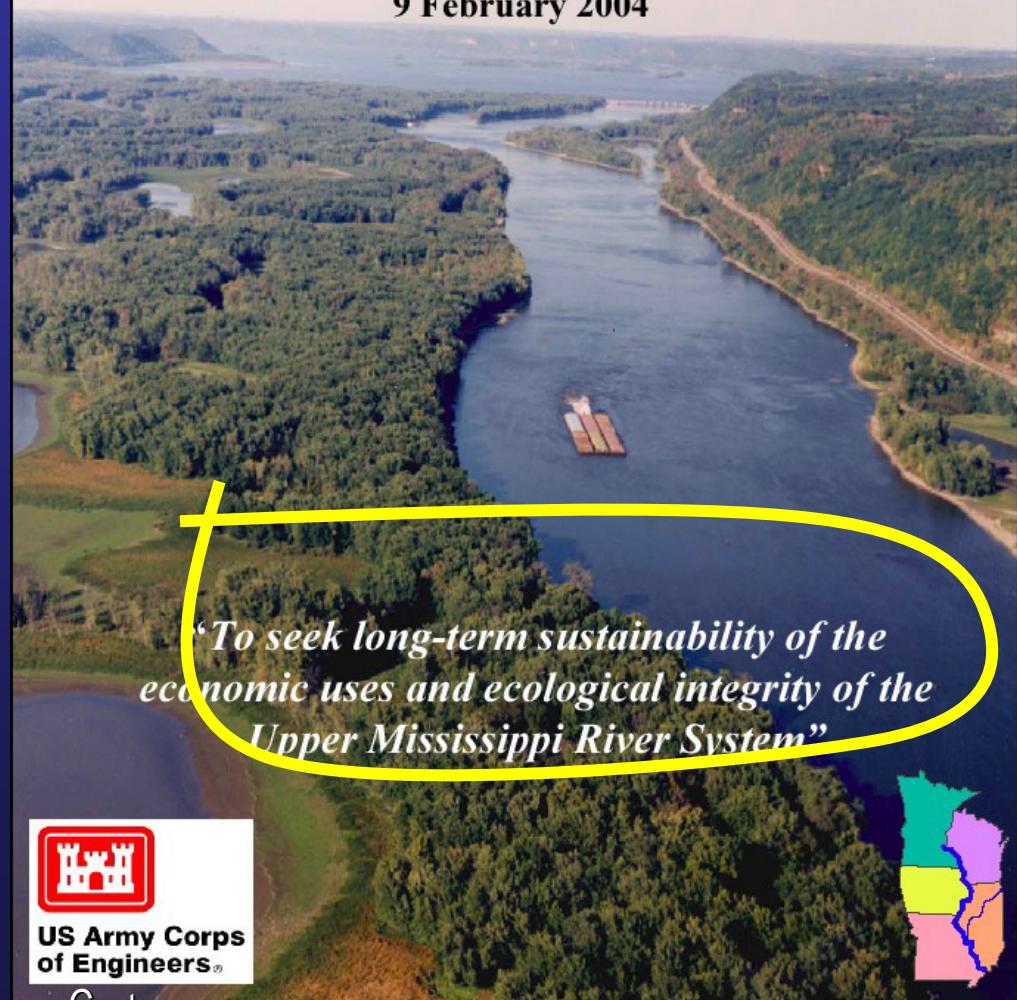
# Science needs on the Upper Mississippi River

## ALTERNATIVE FORMULATION BRIEFING PRE-CONFERENCE REPORT

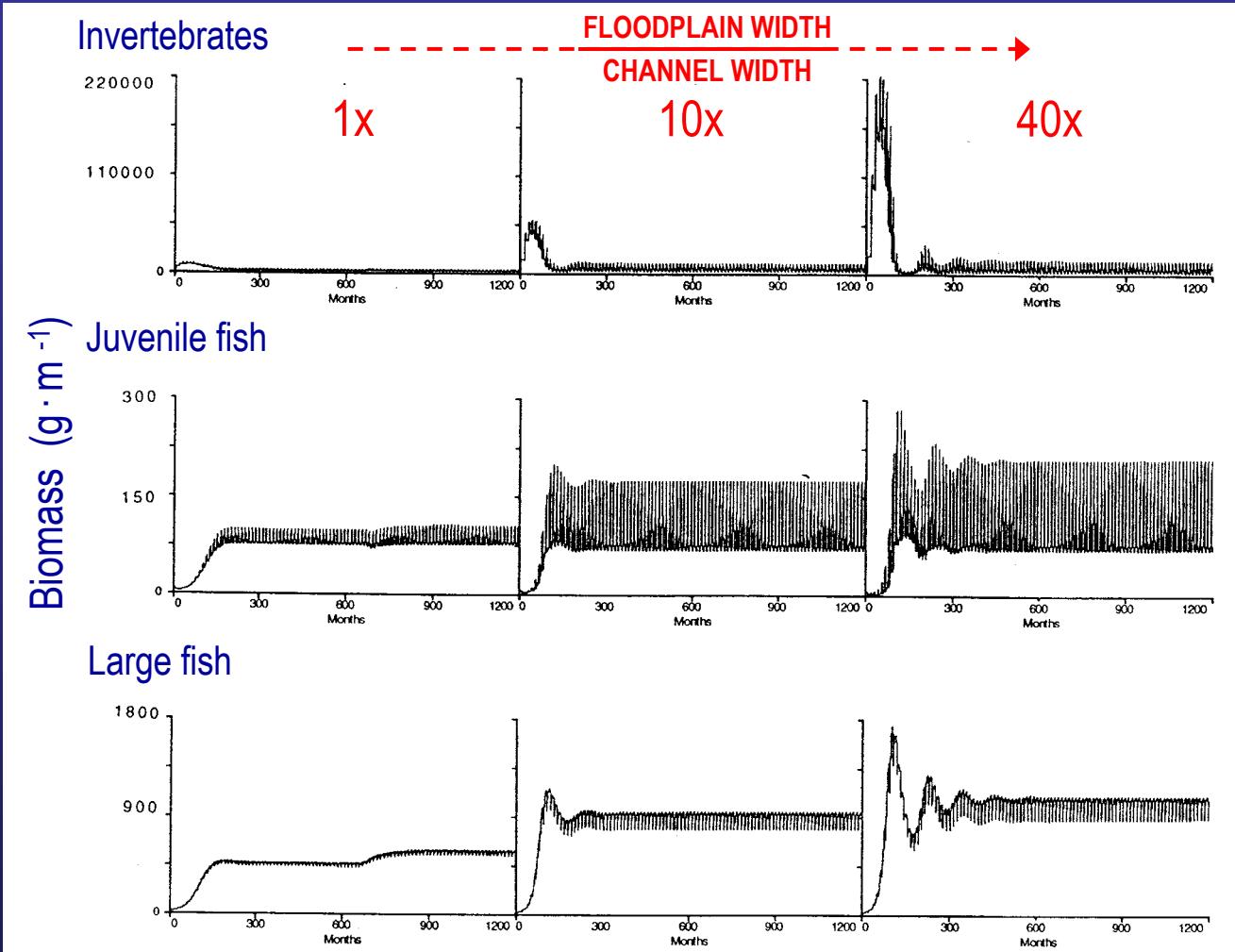
for the

UMR-IWW System Navigation Feasibility Study

9 February 2004



# Restoration will require development of new *predictive* hydrologic- ecologic models



From: Power, M.E., G. Parker, W.E. Dietrich and A. Sun. 1995. How does floodplain width affect river ecology? A preliminary exploration using simulations. *Geomorphology* 13: 301-317.

**Biological production** – the total elaboration of living tissue over space and time – **is the core of ecosystem restoration**

Surrogates:

- Growth rate  $G = P/B$
- Mortality
- Abundance & biomass
- Ecotrophic coefficients (transfer efficiencies)
- In-situ metabolism



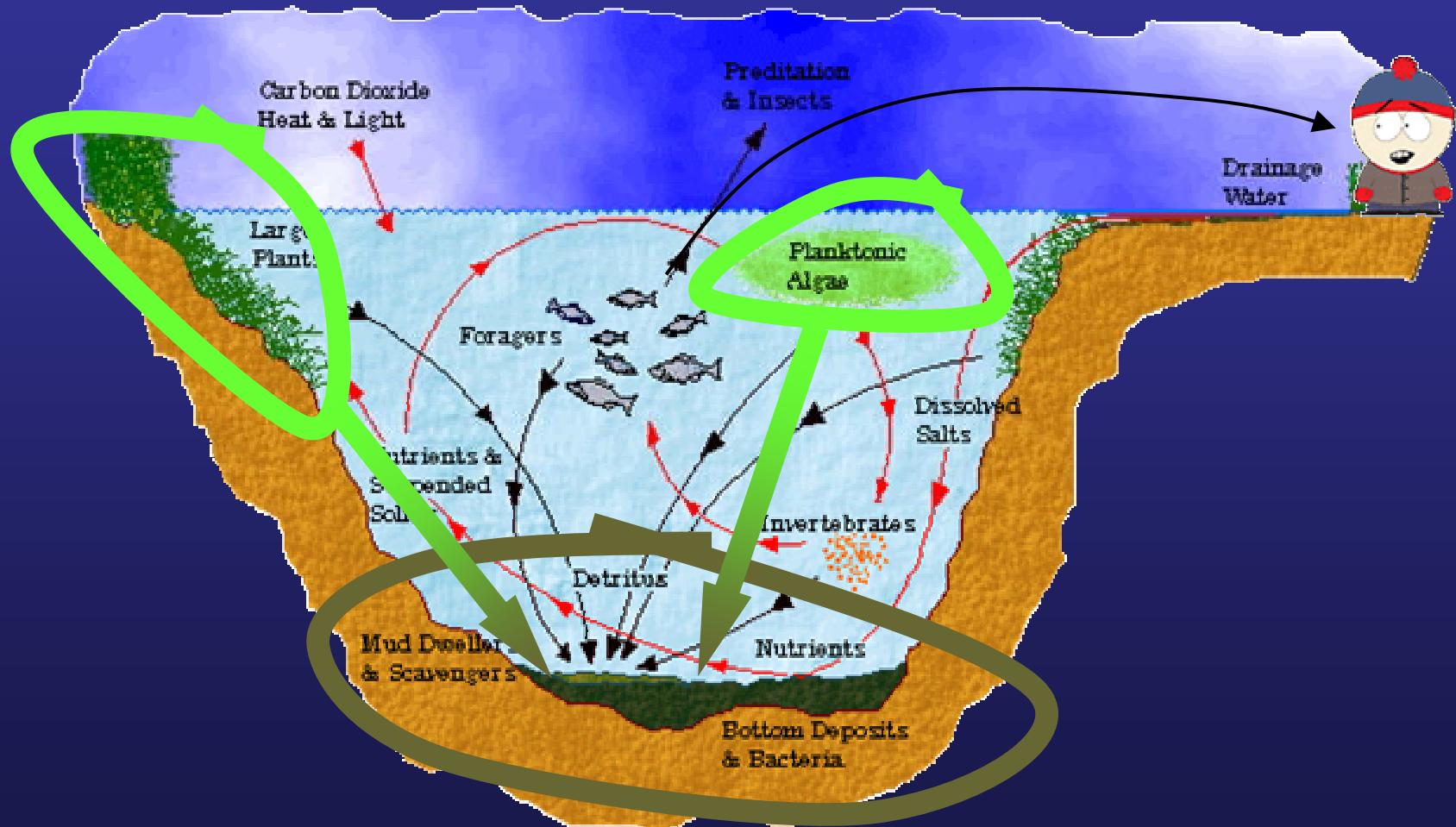
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# Hydrologic linkages with biological production

1. **River continuum concept:** Watershed transport and processing of (terrestrial) C, N, P & K.
2. **Flood-pulse concept:** Floodplain processing of (terrestrial) C, N, P & K.
3. **Riverine productivity concept:** Aquatic photosynthetic C fixation.



# Example # 1: Hydrologic factors influence basal production



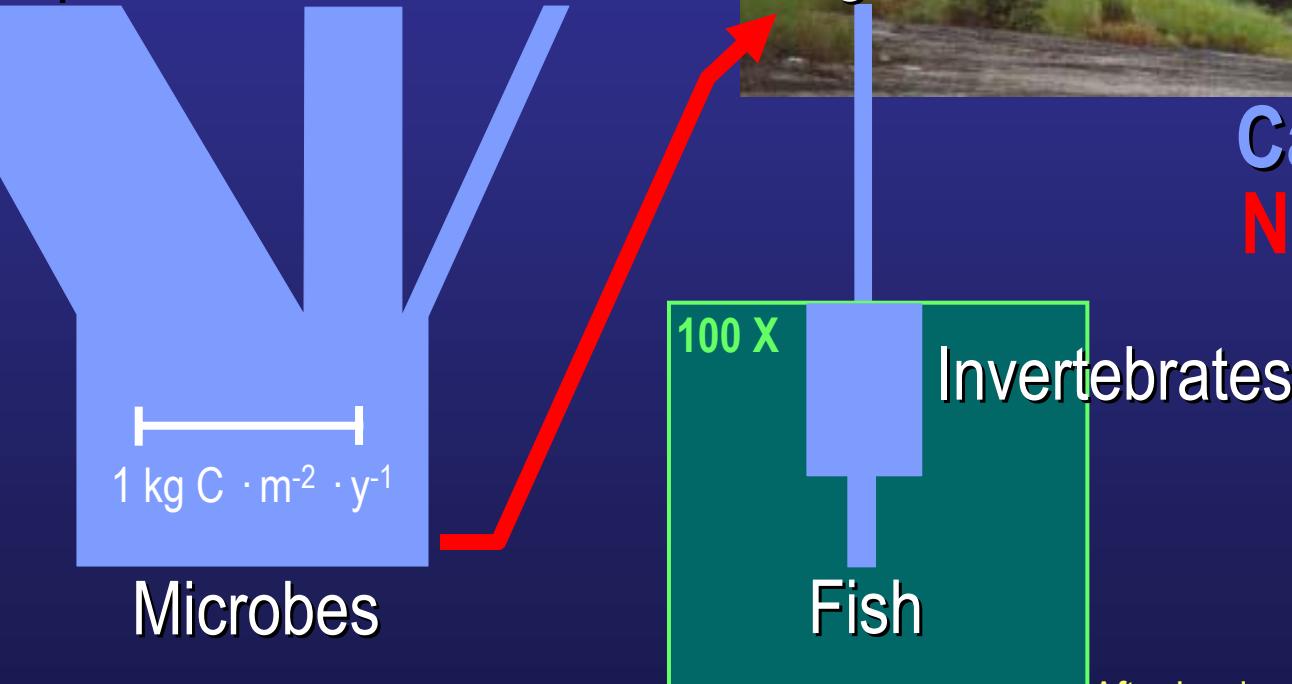
**Observation:** Rivers tend to be heterotrophic

$$\frac{d |\text{CO}_2|}{dt} > \frac{d |\text{O}_2|}{dt}$$

**Assumption:** Production at upper trophic levels is supported mainly by allochthonous carbon sources via microbial pathways

# The evidence: Two production pathways in the Orinoco River

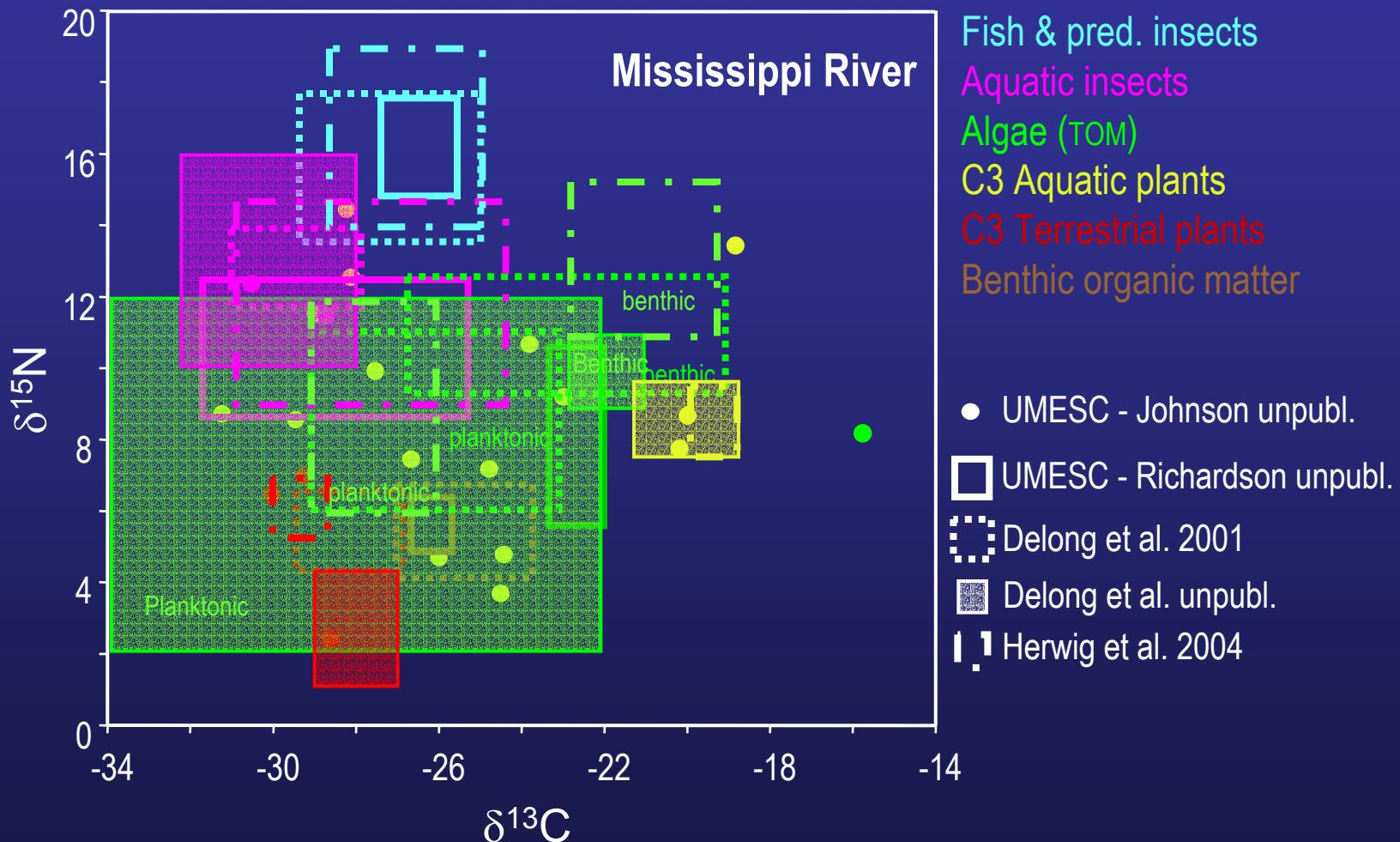
Aquatic plants Litterfall River



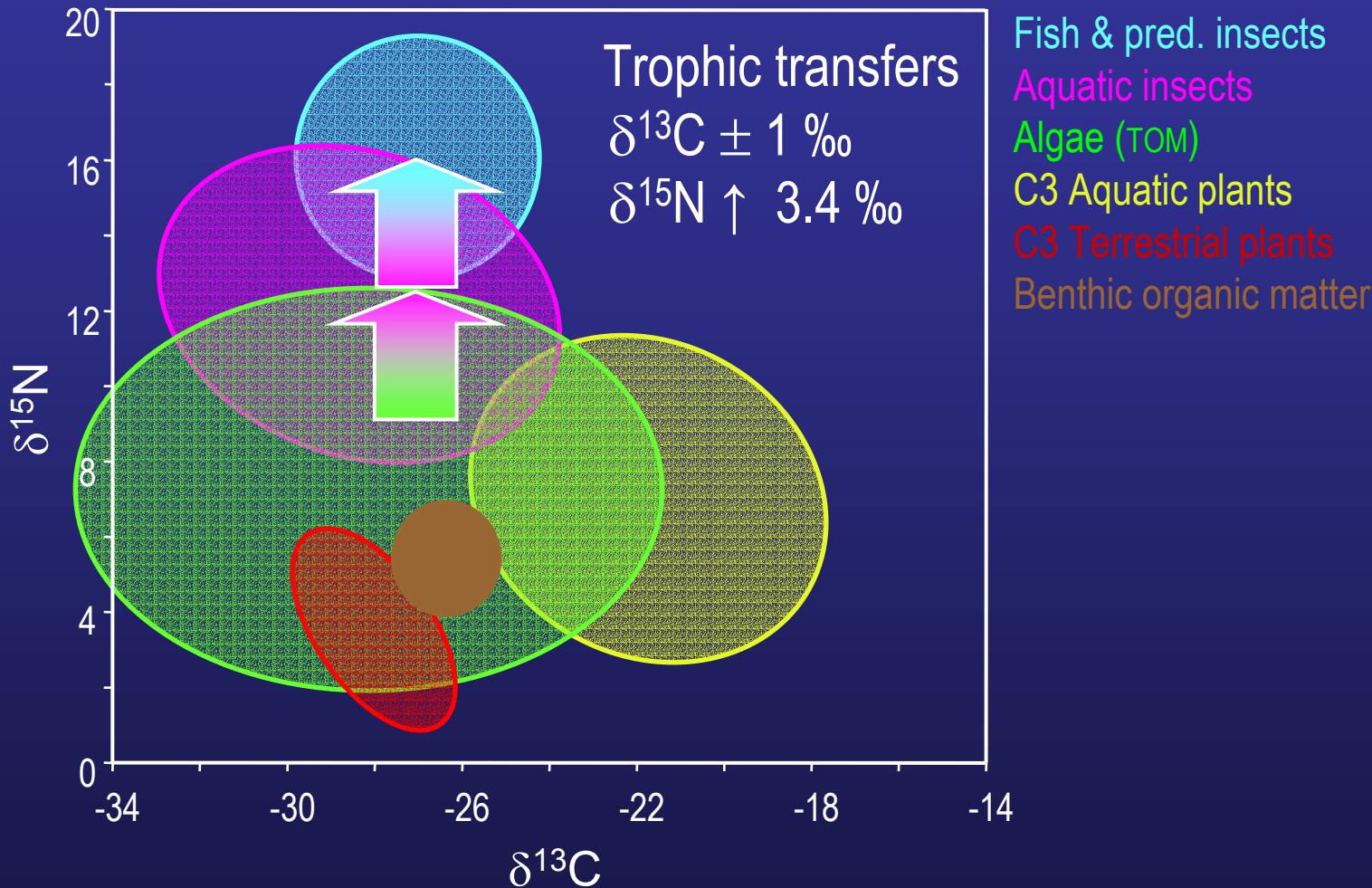
After Lewis et al. 2001. *Journal of the North American Benthological Society* 20:241-254.

# What about temperate rivers?

NOTE: Contains unpublished data—not for distribution beyond this presentation



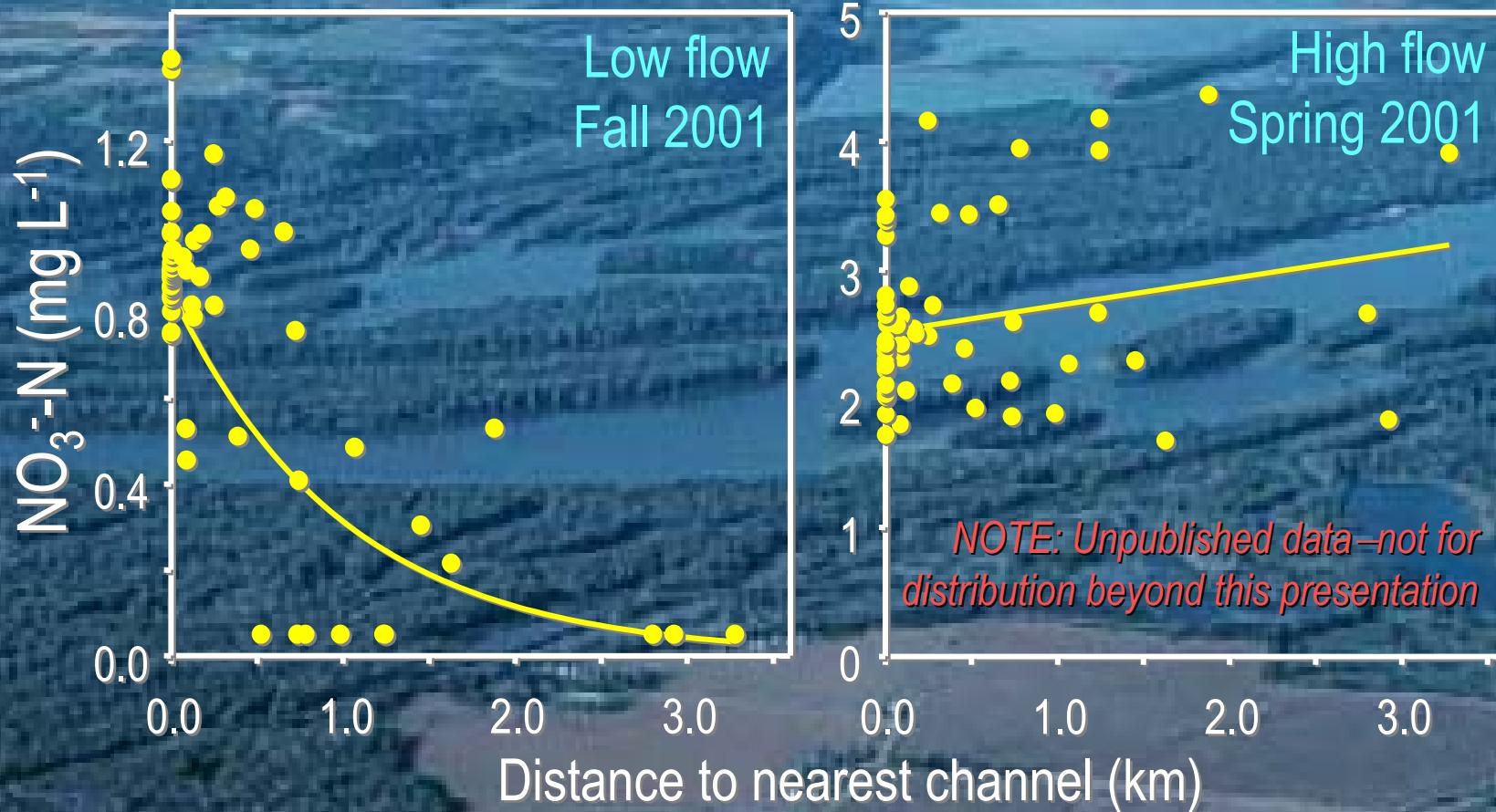
# Algae seem to be the main basal carbon source for fishes of large rivers



# **Primary production, by algae, is strongly influenced by hydrology**

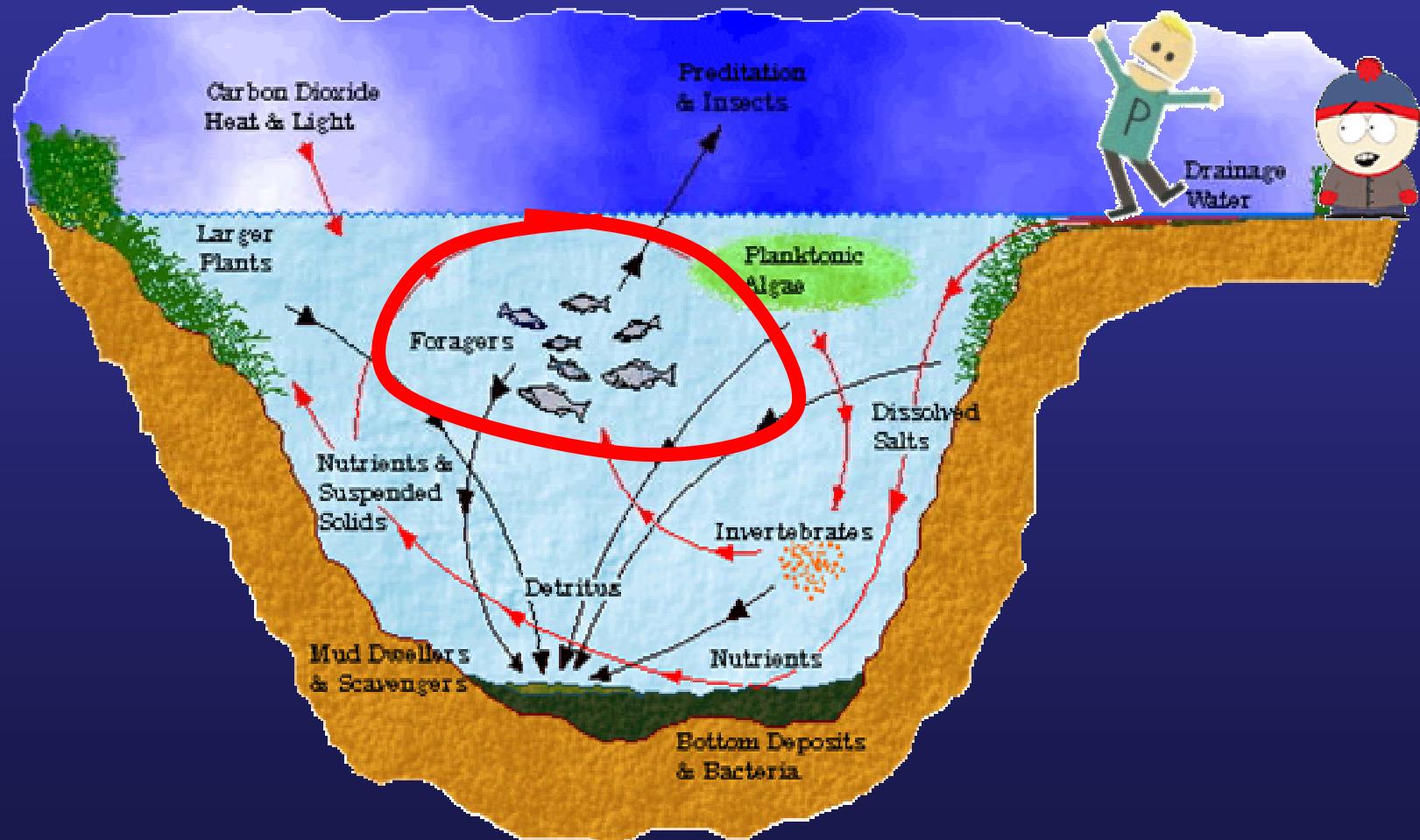
- Dissolved nutrients
- Light penetration (suspended sediments, color)
- Water residence time

# Linking discharge and spatial variability of nutrients



Courtesy Bill Richardson, USGS Upper Midwest Environmental Sciences Center

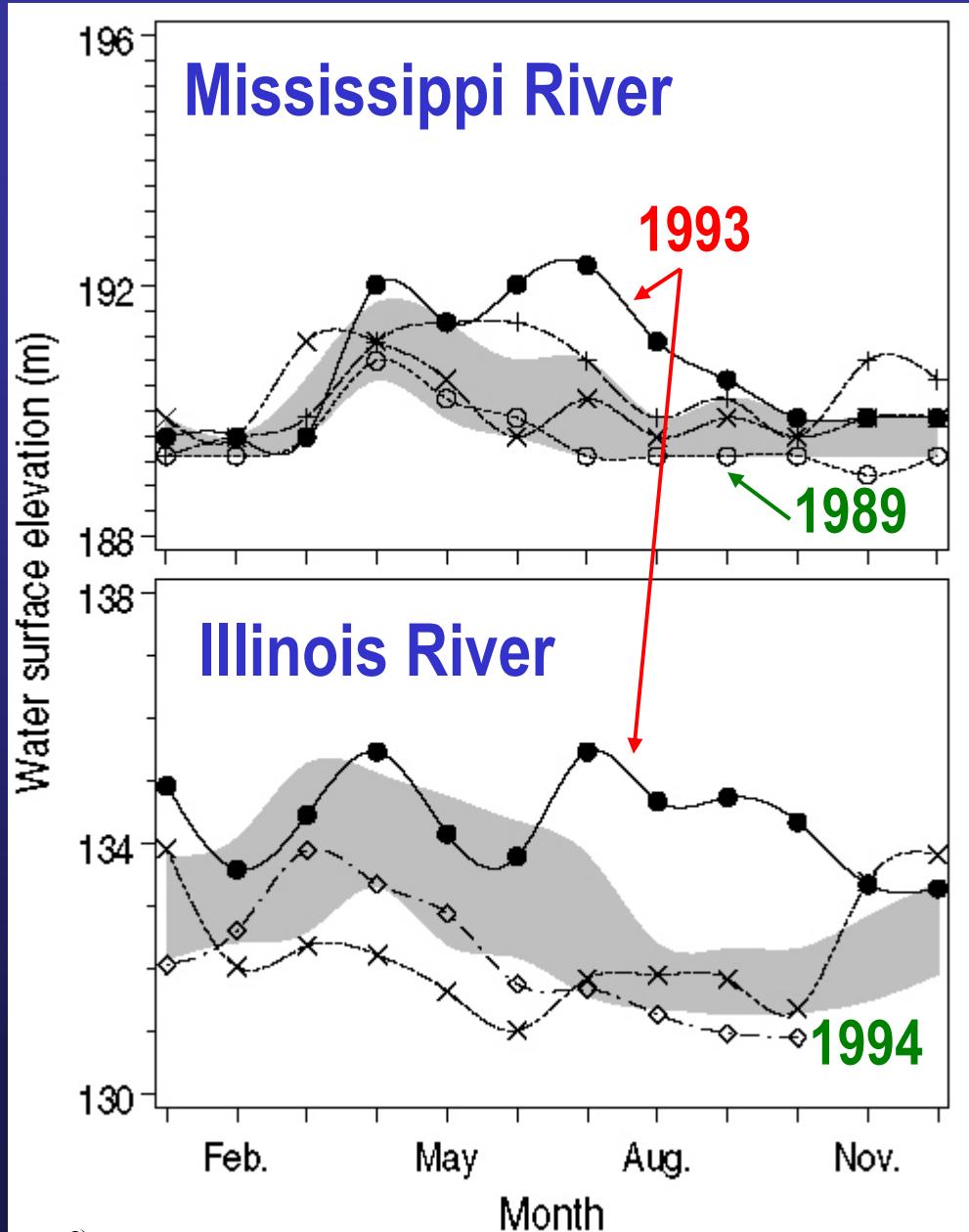
## Example # 2: Hydrologic factors influence secondary production



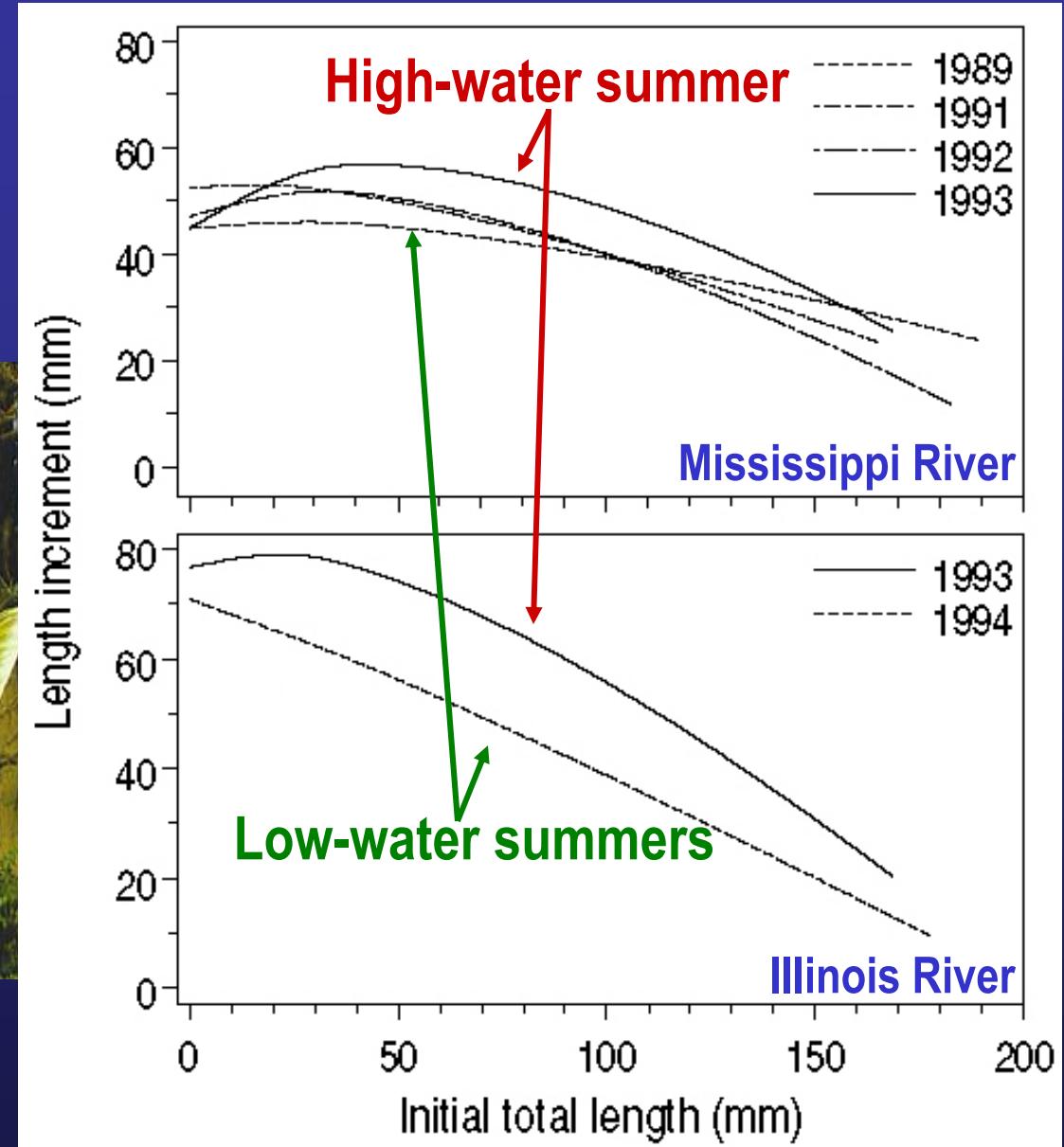
# Evidence for hydrologic controls on P/B at upper trophic levels

Funding: USACE

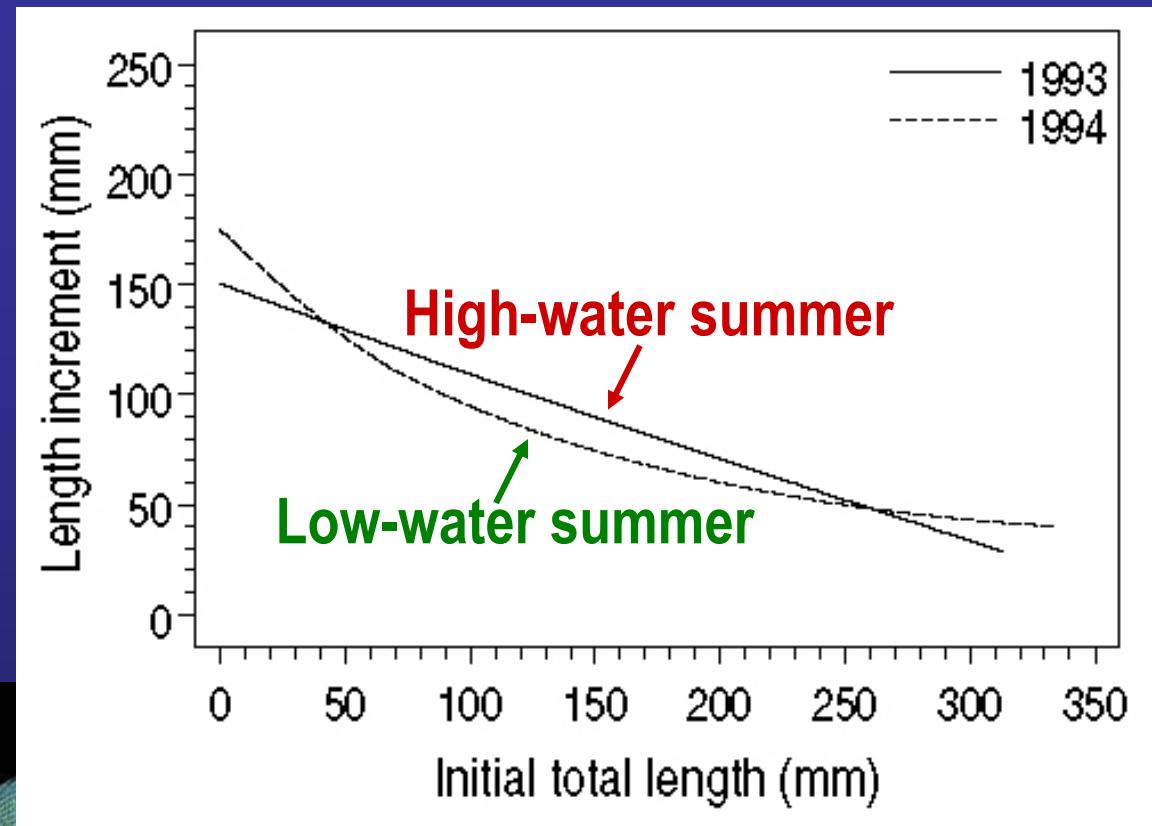
Gutreuter S, AD Bartels, K Irons and MB Sandheinrich. 1999. Evaluation of the flood-pulse concept based on statistical models of growth of selected fishes of the Upper Mississippi River System. *Canadian Journal of Fisheries and Aquatic Sciences* 56:2282-2291.



# Annual P/B of bluegill, a floodplain species

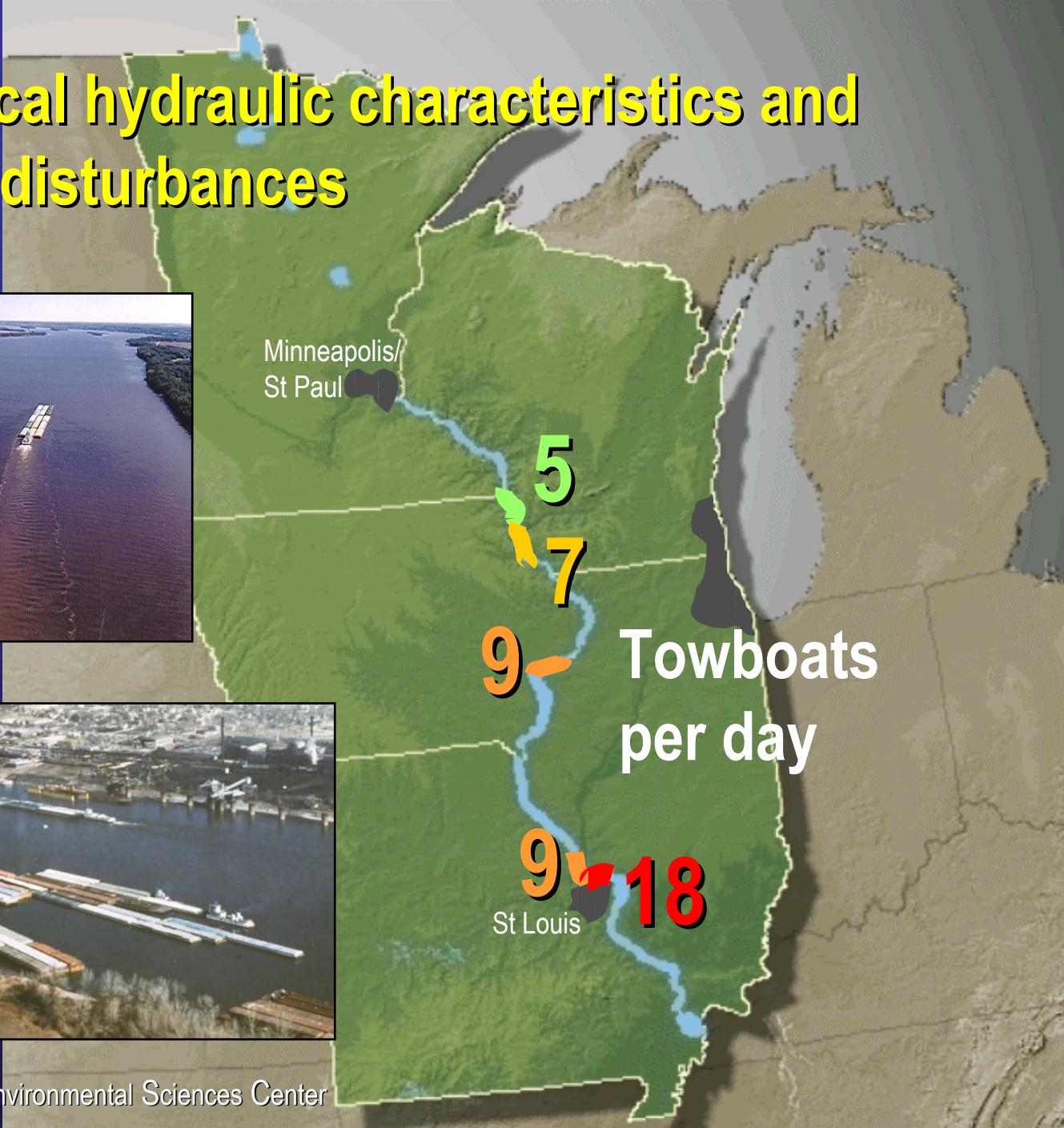
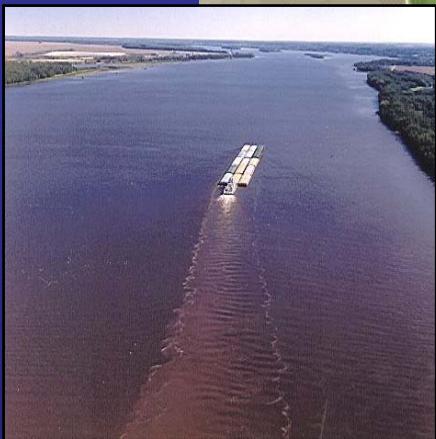


# Annual P/B of white bass, a riverine species



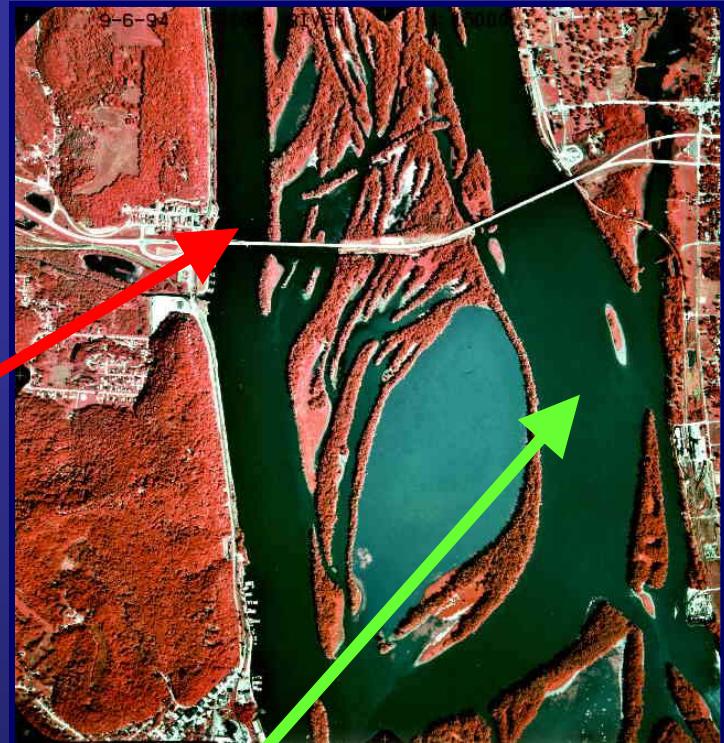
Gutreuter et al. 1999. *Canadian Journal of Fisheries and Aquatic Sciences* 56:2282-2291.

# Example #3: Local hydraulic characteristics and high-frequency disturbances



**Matched adjacent segments of navigation and secondary channel**

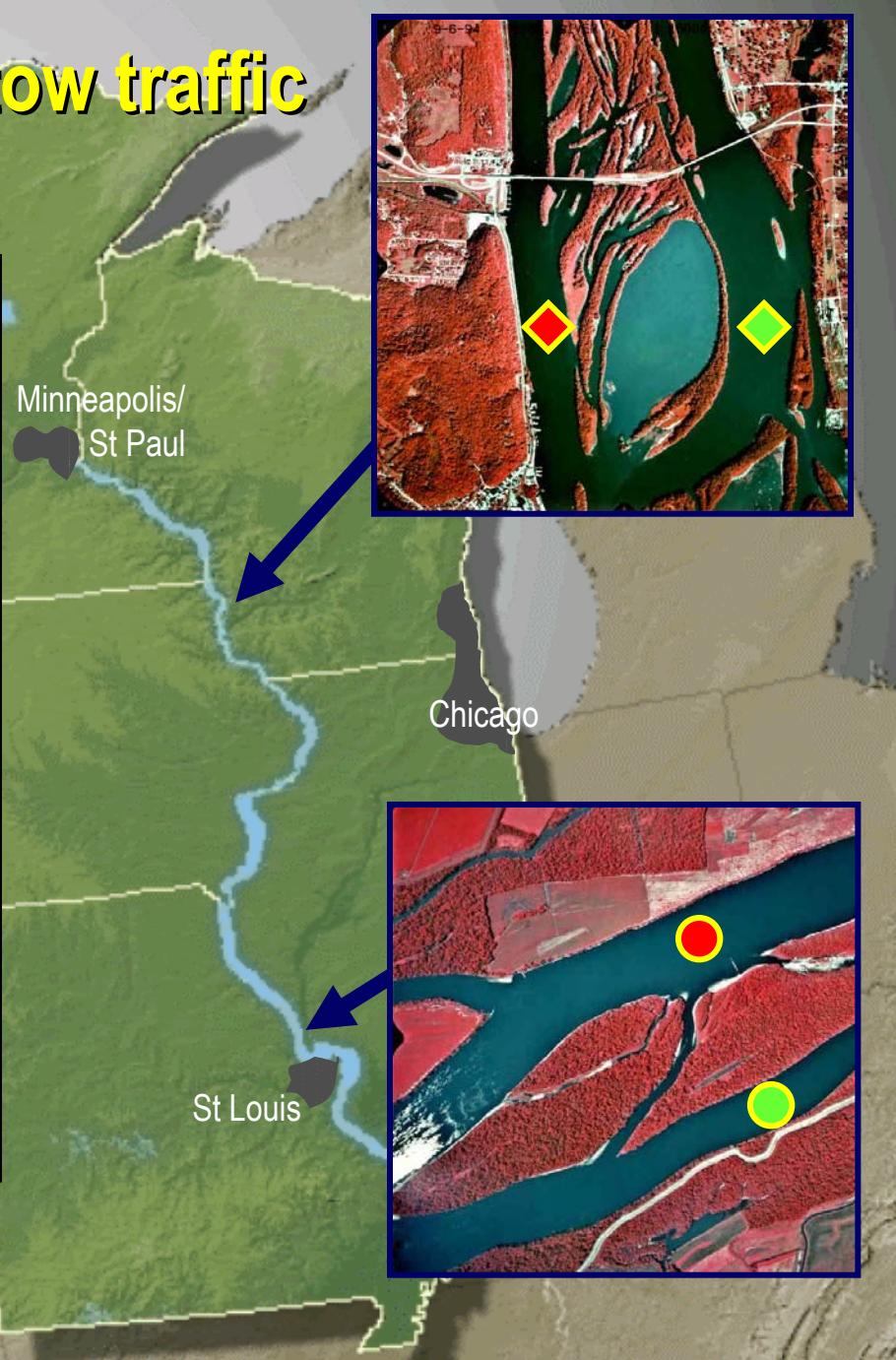
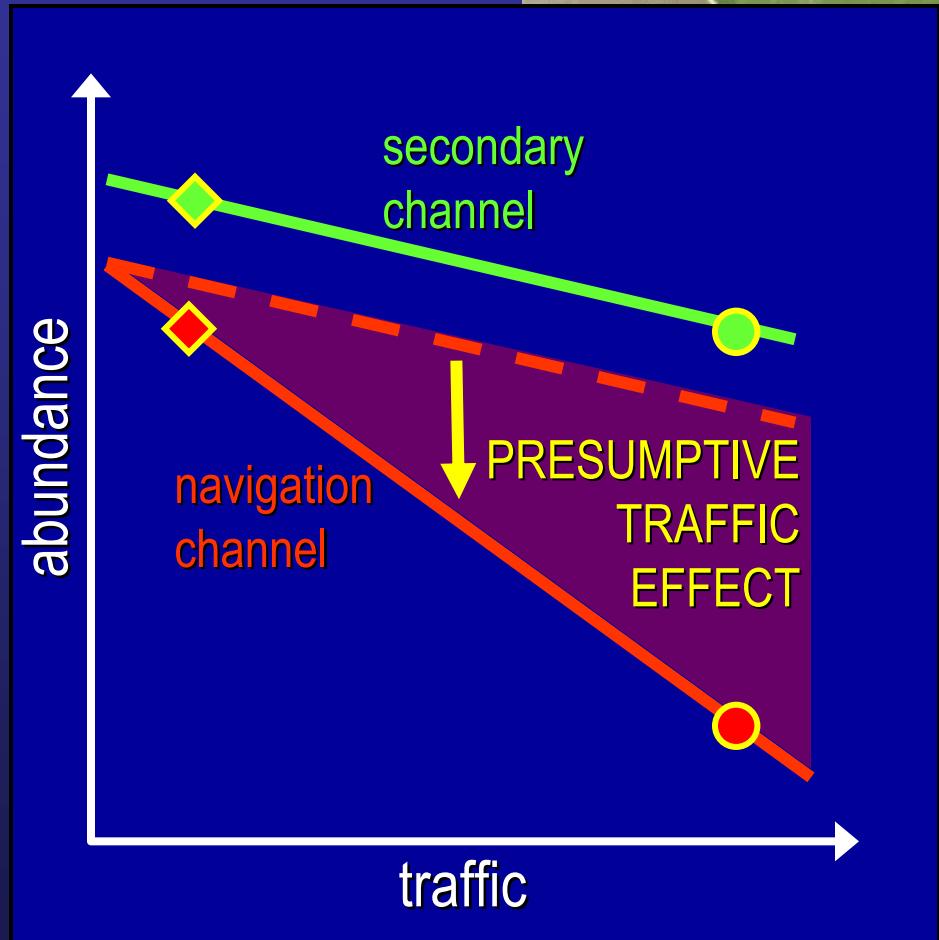
**Navigation channels**



**Secondary channels**

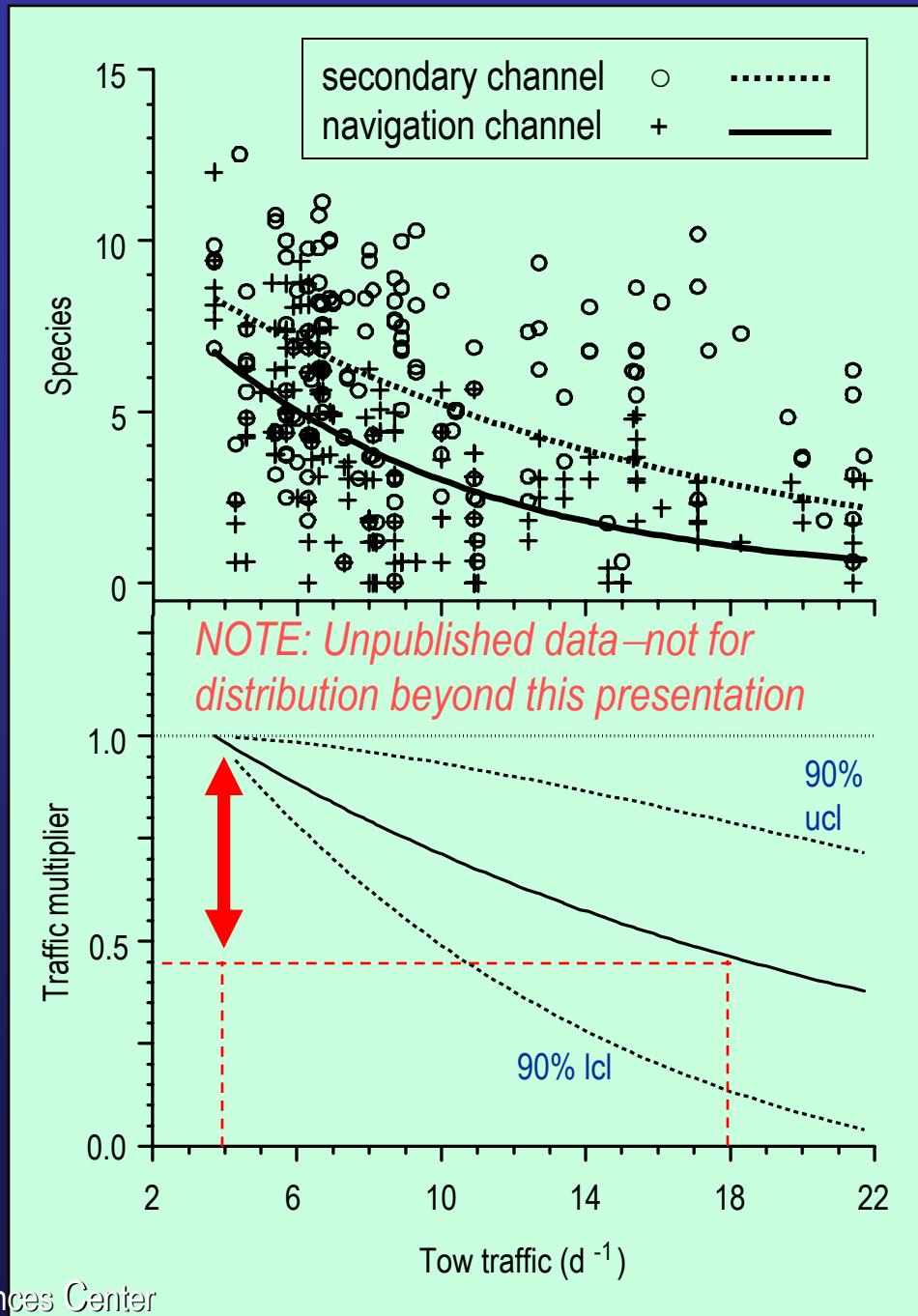
False-color infrared photography  
USGS UMESC

# Identification of an effect of tow traffic



# Traffic seems to affect fish community structure

Sample-wise species density decreases by ~50% relative to secondary channels as traffic increases from 4 to 18 tows/day over past week

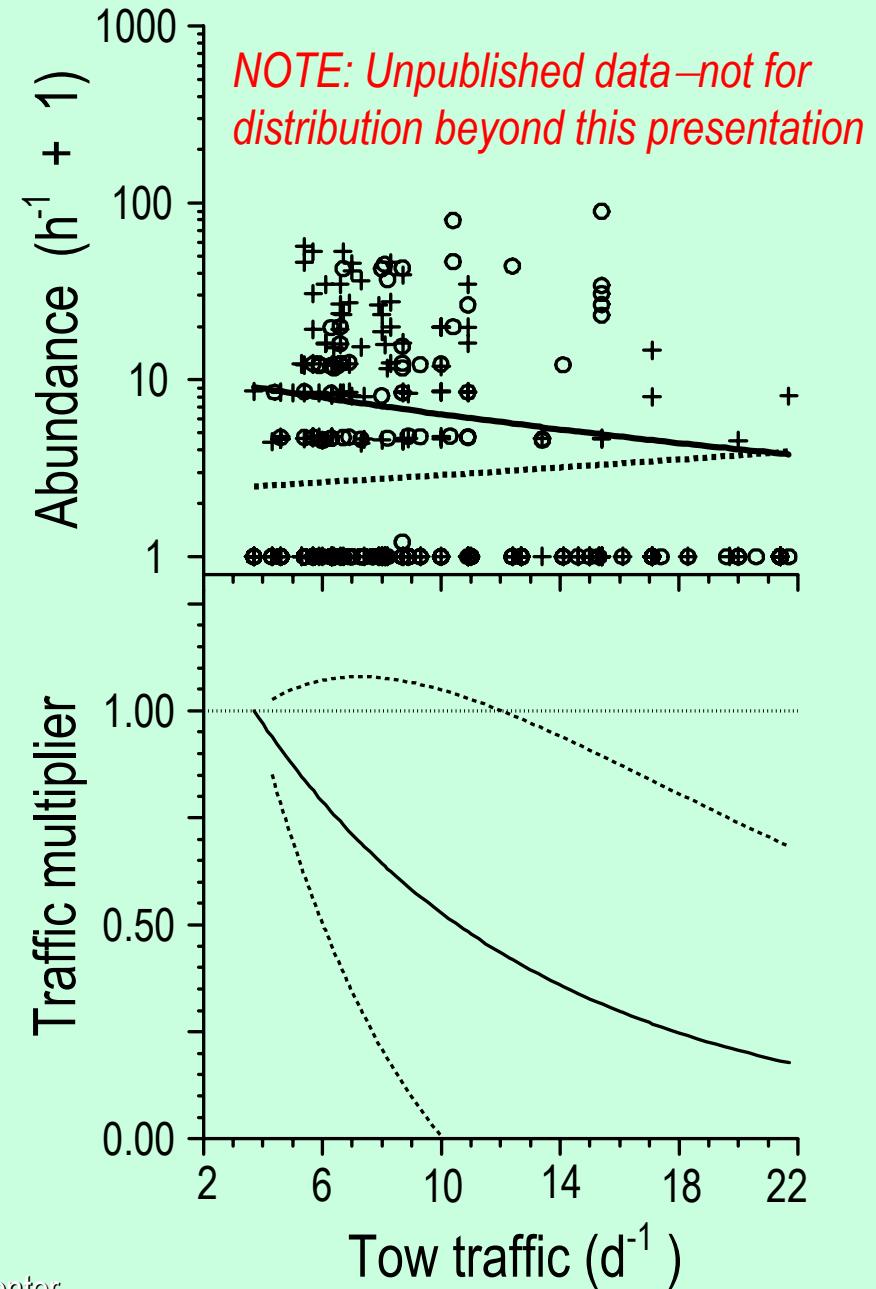


# Traffic seems to affect important channel-dwellers

## Shovelnose sturgeon

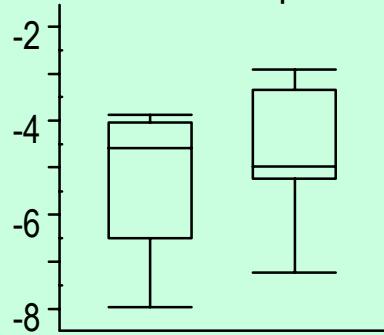


secondary channel     $\circ$  .....  
navigation channel    + —

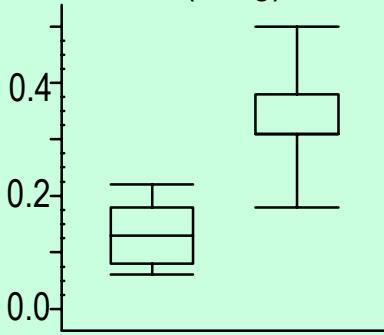


# We didn't find the hydraulic cues...

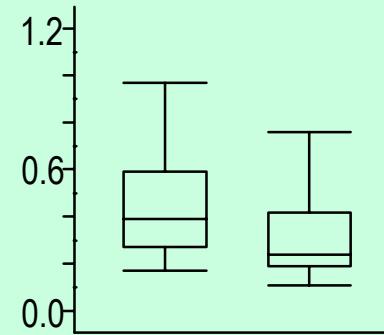
Site depth



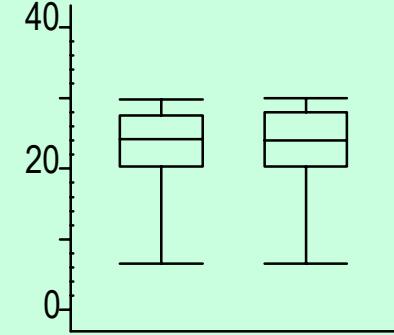
Pr(snag)



Current vel.

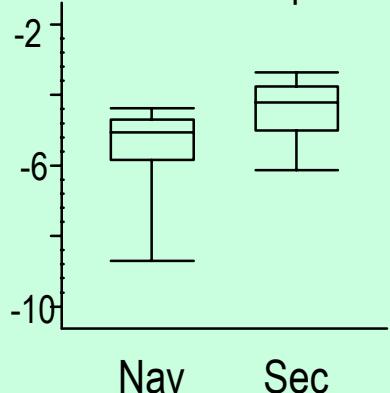


Temperature

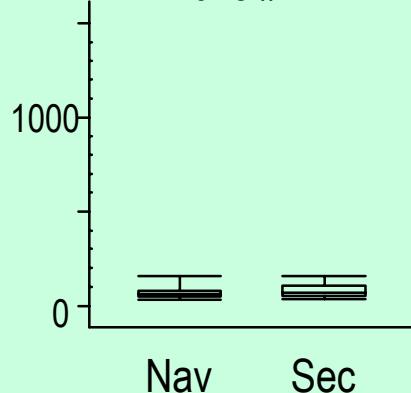


*NOTE: Unpublished data—not for distribution beyond this presentation*

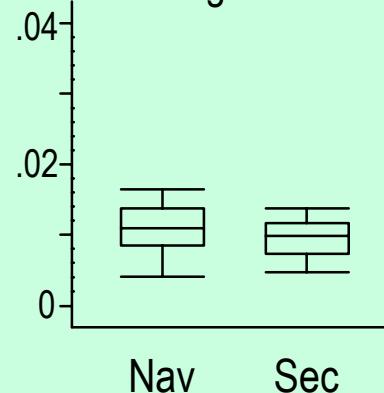
Trawl depth



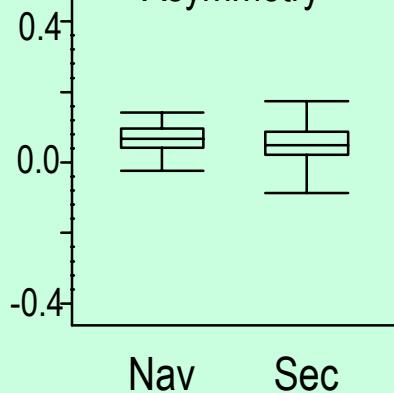
Wave #



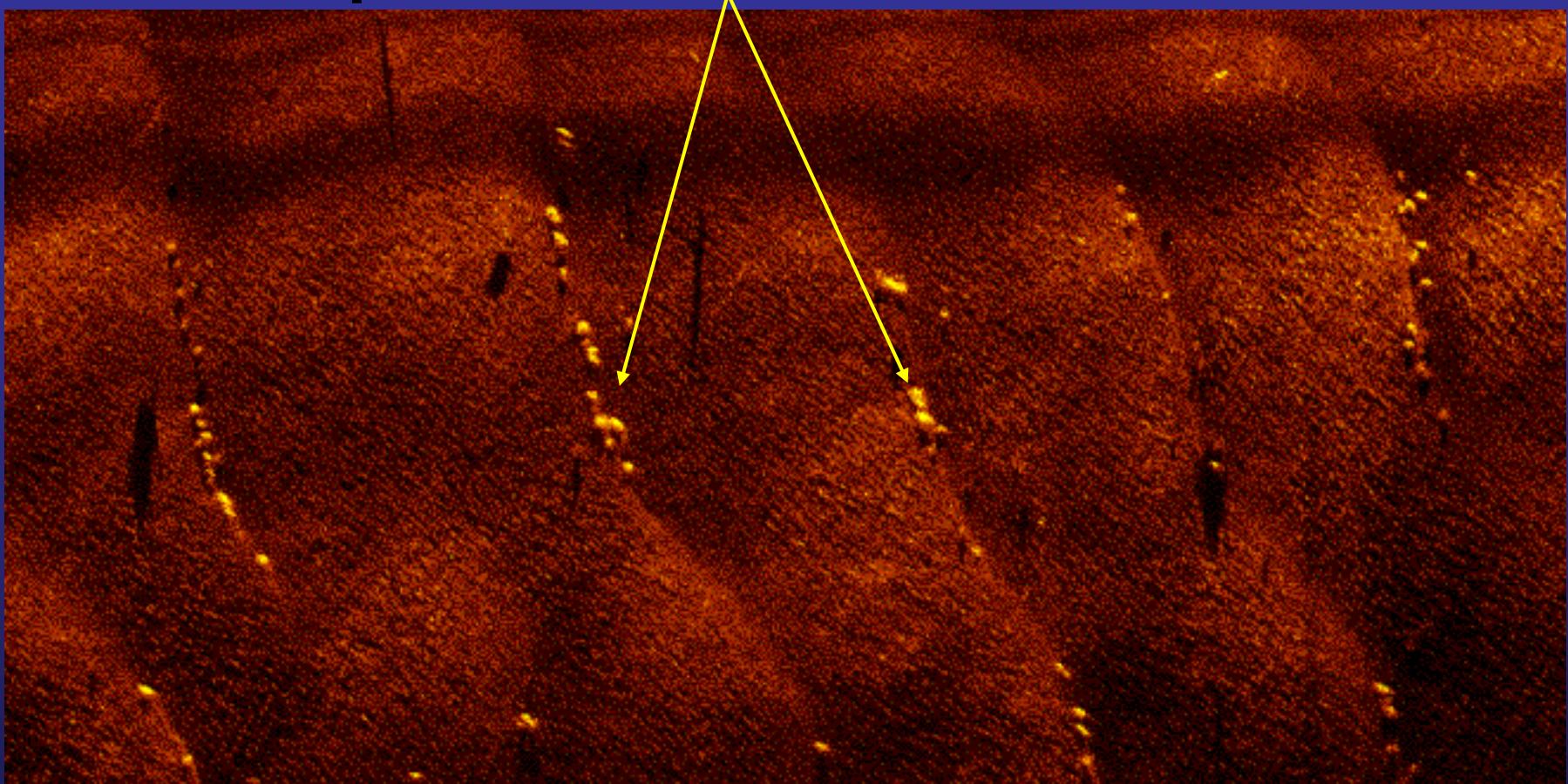
Roughness



Asymmetry



# Bedforms provide fish habitat



Side-scan sonar image of fish echoes in troughs of sand dunes. Courtesy of Aaron Delonay, USGS Columbia Environmental Research Center

# Science needs and opportunities...

- Development of *predictive* ecosystem models
- Measurement of responses of ecological processes to hydrologic change
- Better quantification of food-web dynamics & production processes
- Effects of altered hydrology on carbon & nutrient processing
- Local-scale hydraulic attractors and roles in ecosystem processes (e.g., bedforms, bed load and near-bottom current velocity)





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